The Revolution That Hasn't Happened

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Abstract

In his essay "The Revolution that didn't happen"[1] Steven Weinberg argues that Kuhn's scheme cannot properly describe modern developments in physics and that there has not been a scientific revolution in this field in the 20th or 21st century. I agree with both of Weinberg's claims, but I disagree with his premise in both cases. I propose an account of Relativity Theory and Quantum Physics indicating a coexistence of two paradigms. I suggest that modern developments in physics underline the necessity of a wide approach to the concept of paradigm, but a proper model of their philosophical implications is lacking. It is concluded that modern physics can not be adequately explained applying a cumulative description.

[1] Weinberg, (1998)

Table of contents

1. A brief history of modern physics

Towards the end of the 19th century Newtonian mechanics and classical physics displayed all the characteristics of a unified paradigm. Precise predictions and a comprehensive mathematics at the core seemed convincing. Uncovered territory remained, in physics and certainly in biology, but the fundamental theory provided the direction for future scientific explorations. The confidence in the accomplishments of the field was unequivocally demonstrated by a famous end-of-science statement made in 1894 by the Nobel laureate Albert A. Michelson:

> "The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote. Future discoveries must be looked for in the sixth place of decimals".[2]

Supported by this reliance on scientific advance, a *positivist* perspective of the role of science was maintained. Progress along the established lines was seen as the route to the reality of the physical universe, and an increasing recognition of the deterministic natural laws of cause and effect would be achieved along with our ability to predict and control our surroundings.

At the very outset of the 20th century this outlook changed radically. In 1900, Planck, proposed a theory that light was emitted discontinuously in certain quantities (quanta), entirely disproving the notion of the distribution of light as a continuous wave[3]. Bohr accounted for quantum levels in atomic spectra in 1913[4], and in 1926[5], through further developments by Heisenberg and Schrödinger, the correspondence between waves and the

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[2] Speech delivered at the dedication of the University of Chicago's Ryerson Physical Laboratory

[3] Planck demonstrated that in electromagnetic waves there is no restriction on the wavelength or frequencies, but the energy levels are restricted to values that correlate to a certain fixed unit (Planck's constant). This designated a representation of energy as particles. Planck, (1900).

[4] Bohr described the discontinuous motion of electrons in the Hydrogen atom from their ground state to higher energy levels in such a way that electrons move in precisely defined steps in relation to the nucleus it orbits. The energy levels correlate to the number of electrons it is composed of (not a one-to-one correlation). Bohr, (1913).

[5] Heisenberg accounted for the transition between energy levels by employing matrix mechanics, and described the electron on grounds of the "particle-like" properties of position and momentum. Heisenberg, (1925). Schrödinger reconciled matrix and wave mechanics by demonstrating how they can be reduced to each other mathematically. Schrödinger, (1926).

quanta was formulated. This suggested that, at the atomic level, causal connections - the basic premise of classical physics - had to be revised altogether.

In 1905[6] Einstein published his paper on Special Relativity proposing that qualities like distance and mass could not be completely described without considering their relationship to the observer or the act of measuring the properties. In 1915[7], in his paper *"General theory of Relativity",* Einstein expanded his theory to account for gravitation. In contrast to Newton's flat space and time, gravitation could be reduced to the curvature in the *very structure of* space-time, directly challenging the core of Newtonian mechanics.

2. Kuhn's morphology

In *Structure of a Scientific Revolution*[8] Kuhn depicts a development of scientific communities, catalyst by non-conforming breakthroughs, as questioning their central theories and assumptions. Up to this point, the general consensus in philosophy of science was that of the positivist cumulative description connected with the Newtonian scheme. Scientific development amounts to adding to new truths to the established, by simply extending the theory to which it has been added. Of course, revision and inaccuracies appeared, but the scientific method assured improvement.

Contrastingly, on Kuhn's view, scientific development occurs through recurring states of "*normal*" and "*revolutionary*" stages. Normal stages correspond in many ways to the positivist cumulative view, during which the theory is used and applied while the fundamental assumptions are not questioned. During revolutionary stages, on the other hand, the basic

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[6] Prior to this, the notion of "ether" as a fixed coordinate system was widely held. Einstein "democratized" this perspective by maintaining the speed of light to be constant, but eliminating a selected frame of reference, subjecting all systems to the same physical laws.

[7] In Newton's scheme gravity was seen as an interactive power between physical objects, but Einstein proposed that the perceived interaction could be reduced to the objects "warping" effect on space and time.

[8] Kuhn (1996). Referred to as *Structure* in the following.

elements of the field are examined, and to the extent that these stages amount to more than shifts of mode or special cases of normal science[9].

Central to the notion of revolutionary development is the recognition that underlying any specific scientific field is a set of assumptions and a commitment to some particular knowledge content. This is what Kuhn refers to in *Structure* as a *"paradigm"* or, alternatively, a "*disciplinary matrix"*. The fact that scientific activity relies on such a disciplinary matrix is, in itself, not a radical position, and can be reconciled with the positivist view. The notion that in scientific communities these frameworks are *substituted* with new ones is, however, in direct opposition to positivist view. Kuhn suggests that each individual scientific field is subject to a development in which the body of non-conforming experimental results (*anomalies*)[10] will at some point become so massive that the underlying assumptions are once again examined. Ultimately, if the anomalies cannot be reconciled with the underlying assumptions, they will be abandoned and a new paradigm will be established.

The shift from Aristotelian to Newtonian physics is considered *the* exemplary case of a paradigm shift. Weinberg recognizes this;

> "[the] shift from Aristotelian to Newtonian physics—the shift (which actually took many centuries) from Aristotle's attempt to give systematic qualitative descriptions of everything in nature to Newton's quantitative explanations of carefully selected phenomena, such as the motion of the planets around the sun. (…) Now, that really was a paradigm shift."[11]

Newton explicated motion deterministically, depicting how physical bodies moved in accordance with predictable external properties like gravity and friction, in direct contrast to Aristotle's notion of motion as a quality of the moving object itself. It is evident that

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[9] Kuhn's notion of incommensurability is not addressed in the following, even though this is part of Weinberg's objection to Kuhn's scheme. In my view, the debate on the *teleology* of science can be kept separate from the assessment of contemporary physics and its *morphology*.

[10] Kuhn defines anomalies as challenging the "paradigm-induced expectations that govern normal science". Kuhn (1996), pp. 33.

[11] Weinberg, pp. 52

Aristotle's scheme can in no way be considered a special case of Newton's. And further, that this shift disputes the notion that general physical theories are exclusively established on "pure observation" or that science progresses orderly and inductively.

3. Mature science

Being a trained physicist Weinberg is intimately familiar with the situation in physics today. In his opinion Kuhn's scheme of revolutionary changes does not apply to the situation in physics today. His specific assessment on modern physics is part of a general notion that; *once a science becomes a mature field,* it is no longer subject to revolutionary change.

> "In judging the nature of scientific progress, we have to look at mature scientific theories, not theories at the moments when they are coming into being."[12]

It is argued, that scientific practices are established as fully developed and mature when a scientific field achieves a well-tested theory[13]. Individually, this is not a controversial notion for Kuhn's scheme, but certainly the position that when a theory achieves this status it is no longer subject to revolutionary change is. On this view, a mature theory *is integrated rather than rejected* by the subsequent theory and, hence, does not run the risk of being invalidated by new innovations.

There *are* good arguments for making a case for a strict division between pre-mature and mature science in this regard. Kuhn's scheme is an historical case study, and thus, a *retrospective* approach. On Weinberg's view all case studies in *Structure* are of sciences that are *not mature*. From the moment of maturity, the scientific progress of that field will be of a *cumulative* nature. Specifically, it is advocated, *physics* became a mature theory with Newtonian mechanics. Accordingly, the developments of Relativity and Quantum physics apply to a cumulative model and can be integrated with the Newtonian scheme. Newtonian mechanics and classical physics can be considered special cases of Relativity and Quantum physics. Consequently, when a theory has been sufficiently established its further development does not comply with Kuhn's scheme.

[12] Weinberg, pp. 50

[13] The concept of mature science remains underdeveloped throghout the essay.

> “Revolutions in science seem to fit Kuhn's description only to the extent that they mark a shift in understanding some aspect of nature from pre-science to modern science. The birth of Newtonian physics was a mega-paradigm shift, but nothing that has happened in our understanding of motion since then—not the transition from Newtonian to Einsteinian mechanics, or from classical to quantum physics—fits Kuhn's description of a paradigm shift."[14]

There are further reasons to maintain this position. On Kuhn’s scheme, when facing anomalies, scientific theories resort to one of two strategies; (1) the scientific community becomes fractioned and strives to provide ad-hoc solutions to retain the fundamental theory, or (2) attempts to reconcile the anomalies with the fundamental theory fail and is ultimately overthrown. The activity of both (1) and (2) constitute revolutionary changes and disrupts the productivity of the normal science periods. But neither (1) or (2) provide a good description of modern physics. Although numerous revolutionary achievements have been made in physics in the 20th century, the totality of these successes has not resulted in the rejection of classical physics.

Finally, considering the scientific community, Newtonian mechanics and classical physics remain normal practice and is part of the curriculum of every physics student. Hence, the cognitive habits of classical physics co-exist with scientific work in Relativity and Quantum physics.

> "The greater revolutions of this century, quantum mechanics and relativity (…) are the basis of the physics research of my generation. (…) Our ideas have changed, but we have continued to assess our theories in pretty much the same way: a theory is taken as a success if it is based on simple general principles and does a good job of accounting for experimental data in a natural way. I am not saying that we have a book of rules that tells us how to assess theories, or that we have a clear idea what is meant by "simple general principles" or "natural." I am only saying that whatever we mean, there have been no sudden changes in the way we assess theories."[15]

It seems reasonable to agree that even if theories cannot be ultimately established, it is counter-intuitive to assume that a fundamental physical theory, that has proven efficacious in accounting for a vast range of phenomena, will be relegated to the status of complete

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[14] Weinberg pp. 52
[15] Weinberg, pp. 50

falsification. Further developments will rather be those where the field of validity is adjusted, but the changes made, conform to the basic axioms of the theory.

Glancing at Newtonian physics and the successive developments of Relativity and Quantum Physics it can be argued that it is reasonable to maintain that revolutionary accounts are superfluous. The theories commit to results that do not conform to the Newtonian scheme and have proved outstandingly successful, yet, it remains that this has not resulted in the overthrowing of the grand structure of Newtonian physics.

If granted, Weinberg's assessment of Relativity and Quantum Physics establish a good case for a cumulative account of the major modern developments in physics.

4. Anomalies

4.1. Co-existence

In my view Weinberg's essay leaves out central issues when assessing contemporary physics. The first issue concerns the internal relationship between Relativity and Quantum physics[16]. The two theories are widely acknowledged and co-exist quite peacefully. Considering their applicability, initially it might seem that this is not a major concern.

Firstly, the areas in which general relativity and quantum physics apply are *limited*; general relativity apply to phenomena of great velocities and gravitation, stars and the like while quantum physics applies to subatomic properties. Typically, phenomena of our everyday surroundings can be explained only by applying classical physics. Secondly, although they are both physical theories, they apply to *opposite ends of the field*. Relativity and Quantum physics deal with macroscopic- and microscopic phenomena, respectively.

[16] This point I owe largely to Audretsch (1993).

However, on a closer examination two aspects make this co-existence less plausible. Both theories must be regarded as *general theories*, in that they both suggest that all phenomena are subject to the dynamics they propose and, secondly, they are *incompatible* theories.

(1) In Special Relativity space and time are integrated into a four-dimensional totality, while our perceptions of this totality are relative to our state of motion. General Relativity postulates that gravity is an aspect of space-time itself. Although Relativity dissolves the strict separability of the classical notions of space and time, relativistic systems can be reduced to the sum of its separate components and measurements can be performed without interfering with the system. Relativistic systems are subject to *classical* measurement and comply with the classical notions of *locality* and *predictability*.

(2) Such observer-independency does not comply with quantum mechanical systems. Quantum physics demonstrates our *ignorance* of physical systems. In quantum systems, the precision with which physical properties, like position and momentum, can be measured simultaneously is limited. Generally, the more precisely the momentum is measured, the less precisely the position can be measured, and vice versa. This indicates that quantum systems do not *determine* their future state, but rather determine *possible* future states for that system, each possibility with its own probability. And hence, that causes only *probabilistically* determine their effects by determining all the possible states of the system. If it is granted that quantum mechanics is a complete description, it follows that the measurement displays properties of the system itself, and that between measurements the particle cannot be ascribed specific properties.

On this reading, both theories display many characteristics that comply with those of paradigms in the Kuhnian sense. If granted, this analysis depicts a state of dual paradigms[17] and accordingly does *not* comply with Kuhn's scheme. This is, I think, not a radical position. However, although this is in accordance with Weinberg's claim that Kuhn's scheme cannot properly describe modern physics, this is not an argument Weinberg can adopt. Weinberg's premise for disallowing Kuhn's scheme is that modern physics does not demonstrate anomalies to the extent that revolutionary change is plausible. Oppositely, my premise for the same conclusion is that the contemporary situation *does* demonstrate anomalies to the extent

[17] In Structure there are instances when paradigms co-exist, but these are in regards to pre-scientific periods. Modern physics does not comply with Kuhn's notion of a pre-scientific state.

that revolutionary changes are plausible, but that the nature of the anomalies oppose the morphology of Kuhn's scheme.

Similarly, in regards to the claim that there has been no scientific revolution in modern physics, the difference between mine and Weinberg's positions is actualized further.

4.2. A wider concept of paradigm

In my opinion, a second issue that is not being properly accounted for in Weinberg's essay is the different aspects of a paradigm. Consider again the shift from Aristotelian to Newtonian physics; Newton's insight that motion could properly be explained mechanically established, initially, a change in the equations themselves, and subsequently stimulated a general examination of the concepts of motion. At the time, these concepts were still derived from Aristotelian notions of the inert qualities of physical bodies, but were reconstructed in accordance with the mechanical theory. Ultimately, the totality of Aristotle's theory of motion and its metaphysical framework shifted. This revolutionary shift is admitted by Weinberg on the premise that Aristotle's scheme was not a mature theory - dissimilar to Newton's. Although there is a lot to be said for the superiority of the latter in regards to maturity, a more general view of Newton's scheme makes this sharp divide less tenable.

I agree with Weinberg that Newton's scheme is most successful. For any general theory its status is closely connected to its ability to extend its domain of application. The Newtonian scheme had a remarkable ability to extend its range continuously, explaining an increasing number of areas and processes and providing increasingly precise predictions. But the success and uncontested status of Newtonian mechanics and classical physics at the end of the 19th century is integrally connected to a conceptual framework, and this makes it more vulnerable. Particularly, two notions, metaphysical and epistemological respectively, are indispensable:

(1) *Determinism*. This is, simply stated, the view that every event is causally determined by prior events. Or in the infamous words of Laplace;

> "We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes."[18]

(2) *Naïve* or *direct realism*; the position that we perceive the world exactly as it exists. This notion enables the classical observer that perceives reality directly without interfering with it.

Some degree of the interconnectedness of the Newtonian scheme with determinism and direct realism, I think, is easily admitted, regardless of ones commitment to any particular philosophy of science. Thus, if one commits to a cumulative position on modern physics, one must commit to one of two positions:

(A) The metaphysical and epistemological aspects of the Newtonian scheme are not challenged (and, hence, there will be no revolutionary change), because the theories in modern physics are compatible.

(B) The metaphysical and epistemological aspect may be substituted, but this will not constitute changes of a revolutionary nature. Possible incompatibilities in modern physics are mainly in regards to the conceptual framework, and, in itself, changes in the conceptual framework are of a lesser significance. In solidifying his assessment, Weinberg advocates the latter position[19].

> "It is important to keep straight what does and what does not change in scientific revolutions, a distinction that is not made in Structure. There is a "hard" part of modern physical theories that usually consists of the equations themselves (…) then there is a "soft" part; it is the vision of reality that we use to explain to ourselves why the equations work. (…) The soft parts change (…) But after our theories reach their mature forms, their hard parts represent permanent accomplishments"[20]

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[18] Laplace. pp 4

[19] Above, Weinberg advocates position (A); "No aspect of modern physics is subject to revolutionary change, because its theories are compatible".

[20] Weinberg, pp. 50

Weinberg's argument rests on the ability to make plausible the casual (loose) connection between the different aspects of a paradigm; if he can maintain this casuality the anomalies of modern physics are of lesser significance, and the theories sufficiently coherent to allow his reductive analysis. As denoted above a paradigm is *a set of assumptions and a commitment to some special knowledge content*. This definition fits well with Weinberg's argument, as it designates the status of the equations themselves as the main issue to be resolved. In the passage above, this aspect of a paradigm is detached from the conceptual framework completely.

In Kuhn's scheme, conceptualization is *the* central notion in establishing a scientific community or in the case of a paradigm shift; *reconceptualization*. Contrastingly, Kuhn advocates a close connection between the aspects of a paradigm and demonstrates this by suggesting how the emergence of anomalies reveals this. Scientific theories rest on observation, and in periods of normal science the observations that are made conform to each other and constitute a coherent model. When normal science is disrupted by the emergence of anomalies two things occur; the latency of the underlying assumptions become evident, and exactly how interwoven the axioms themselves are to a conceptual framework is made evident.

> "(…) two men whose discourse had previously proceeded with apparently full understanding may suddenly find themselves responding to the same stimulus with incompatible descriptions and generalizations"[21]

Scientific observations occur within a scientific community and are made by subjects that are familiar with a general scheme, and its relevance can under no circumstances be dismissed altogether. Assembling of data is to interrelate observations and ascribe them as coherent with a conceptual framework.

> "The point I have been trying to make is a simple one, long familiar in philosophy of science. Debates over the theory-choice cannot be cast in a form that fully resembles logical or mathematical proof. In the latter, premises and rules of inference are stipulated

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[21] Kuhn pp. 201

> from the start. If there is disagreement about conclusions, the parties to the ensuing debate can retrace their steps one by one, checking against prior stipulation."[22]

In my opinion this is indeed a simple point, and I do not consider it to be a radical one. In fact, considered isolated, I think that Weinberg does not object to it. However, this *is* his premise; a mature science can be excluded from revolutionary changes, precisely and solely, because it is capable of providing observations that are not theory-laden.

> "these changes have been evolutionary, not revolutionary. Nature seems to act on us as a teaching machine. When a scientist reaches a new understanding of nature, he or she experiences an intense pleasure. These experiences over long periods have taught us how to judge what sort of scientific theory will provide the pleasure of understanding nature."[23]

In this respect, Weinberg's *mature/pre-mature-scheme* is equivalent to a positivist view as he adopts the classical observer and direct realism exhaustively. Consequently, Weinberg extends his position by advocating that Kuhn overemphasizes the extent that the *soft* parts change.

> " Some of what Kuhn said about paradigm shifts does apply to the soft parts of our theories, but even here I think that Kuhn overestimated the degree to which scientists during a period of normal science are captives of their paradigms."[24]

This is at the very least consistent. It would seem arbitrary to argue that the metaphysical framework or "*the vision of reality that we use to explain ourselves why the equations work*" is subject to unlimited change and can be completely transformed while "*the equations themselves*" remain valid. This is true of mathematical equations, as laid out by Kuhn above (because they do not rely upon a metaphysical framework); all the premises are articulated and agreed upon, and confirming them is a matter of examining the procedure. I assume that Weinberg means something more than this with "*the equations themselves*". On such a perspective, the shift from Aristotle's to Newton's paradigm can be construed as evolutionary to the extent that the predictions of Aristotle's theory are correct. To strictly separate hard and

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[22] Kuhn, Pp. 199. This passage is in the context of commenting on his notion of incommensurability, but pertains to the debate on theory-laden observations and interaction of "soft" and "hard" parts

[23] Weinberg, pp. 50

[24] Weinberg, pp. 50

soft parts of a mature science, is a case of reducing "*the vision of reality that we use to explain ourselves why the equations work*", to this purpose alone.

My objections to Weinberg's position are all connected to his downplay of the significance of conceptualization. By considering a physical theory within the full extent of its metaphysical framework, it is hard to conduct a positivist model. As a general approach to an assessment of modern physics I would like to go in the other direction and employ a broader perspective of a paradigm; not only the equations themselves but their metaphysical and epistemological framework. It is in my opinion in regard to this further aspect[25] that the extent of emerging anomalies can be properly recognized and evaluated.

5. Conclusion

Conceptualization pertains to the general debate of observation, but ironically, the issue is specifically actualized by modern physics, in particular by quantum mechanics.
Considering the notions of "wave-particle duality" and "non-locality" the direct opposition to the metaphysics of the Newtonian-scheme is accentuated.

The conventional approach in providing a physical model to quantum mechanics is the "Copenhagen interpretation". A quantum system is described by a wave function representing a mixed state of possible values. When a measurement is performed the system is ascribed one of the values of the wave function. This is the "collapse of the wave function". In classical systems, it is assumed that whenever a measurement is conducted it reveals the properties of the object, and does in no way constitute the phenomena, such that the state of systems when they are measured reflect the state of those systems also when they are not

[25] there is often mention of a third aspect of a paradigm in *Structure*; the experiments and instruments themselves. This is a significant aspect that underlines if anomalies detect a flaw in a central instrument, this can expose inadequacies in the fundamental theory. However, I leave out further remarks on this matter.

measured. This is the view that under ideal conditions we see objects exactly as they are. In quantum systems the location of the particle is registered when the wavefunction collapses, but given that the wavefunction represents a complete description of the state of the system the particle is in a "superposition" of the possible states of the wave function in between measurements. Subatomic particles display both wave-like properties and particle-like properties, and the definite values that we ascribe to particles can not be maintained as a general description. It seems that the definite properties are as constitutive of the experimental set-up as of the particle itself.

Einstein's was convinced that particles must have well-defined properties with exact values between measurements, and regarded that quantum mechanics must be an incomplete description. Along with Podolsky and Rosen, Einstein[26] demonstrated how it can be deduced from quantum mechanics that certain particles retain *interconnectedness* even at a distance, and construed a thought experiment, that revealed absurd implications. It describes an experimental set-up with two particles that are emitted simultaneously in opposite directions that subsequently register in linear polarisers. The polarisers can register one of two outcomes, + or -. The particles are "entangled" in such a way that they have opposite values of the same property. Hence, if a measurement of the first particle yields +, the measurement on the other yields - . This should happen simultaneously and regardless of the distance between them.

Alain Aspect and his colleagues carried out this experiment in 1982, and the results conformed to the predictions of quantum physics. The Aspect-experiment was conducted using a device ensuring that the value being measured was selected randomly, and a distance between the measurements that any causal connections between the particles would have to travel at a speed greater than the speed of light. The experimental results retained the interconnectedness between the two particles, such that the measurement on the first particle decided the measurement of the other. If this is regarded as complete, it violates *locality* as the range of properties cannot be ascribed to the particles individually.

The Copenhagen interpretation separates between a deterministic measuring apparatus and a probabilistic quantum system, and thus applies a hybrid-scheme. Generally, a proper physical model ought to account for all of its systems as subject to the same physical laws. Further, it

[26] Einstein, Podolsky and Rosen. (1935)

provides no analysis of the collapse of the wave function besides ascribing it to observation itself, and restricts the purpose of physics to deliver consistent experimental results. Schrödinger's infamous thought experiment was construed to demonstrate the absurdity that follows from ascribing the particle acquiring definite properties to observation itself; the cat would remain in a state of probability of dead or alive until an observation is made. However, it remains that exact properties of the mixed state of probabilities is determined exactly when a measurement is performed, and that the hybrid-model of the Copenhagen interpretation is regarded as the closest thing we have to a general conceptualization of quantum mechanics.

Ever since its conception quantum physics has contended most common-sense notions about natural laws. Throughout this period there have been continuous attempts to comprehend these challenges, yet there remains somewhat of a void where the metaphysics should be established. The underdevelopment of the metaphysical and epistemological challenges of Relativity and Quantum Physics is in my opinion what enables Weinberg to make it plausible that evolutionary changes can be retained as a sufficient account of modern physics.

Strategically, there *is*, however, a consensus: The ongoing search for unification between Relativity and Quantum physics is a joint effort - rejection of is a non-issue. Hence, the test for a proper paradigmatic assessment of modern physics should address the nature of a unified theory. Weinberg does not acknowledge the radical nature of this project:

> "We hope that in the next great step forward in physics we shall see the theory of gravitation and all of the different branches of elementary particle physics flow together into a single unified theory. This is what we are working for and what we spend the taxpayers' money for. And when we have discovered this theory, it will be part of a true description of reality."[27]

To achieve this without revolutionary change requires that an epistemological and metaphysical framework that properly accounts for Relativity and Quantum physics, can integrate naïve realism and determinism in an evolutionary manner. I object to this, and the position that an abandonment of the classical concepts of *observer-independence* and *locality*, or in Weinberg's words that "the soft parts change", does not constitute revolutionary change. Generally, I argue that modern scientific theories can not provide a foundation that is not

[27] Weinberg, pp. 52

theory-laden. Specifically, I argue that the developments in physics in the 20th century underline this position and, themselves, make an argument that scientific development remains revolutionary. The shift from Aristotelian to Newtonian physics is upheld as an exemplary case of revolutionary change in the history of science, yet, ironically, Aristotles notion of potentia[28] or potentiality ("essences of natural bodies") seems in some respects, closer to the metaphysical direction of a unified theory than to that of the self-sufficiency and singularity of classical physics.I think it bold to state that a successful physical theory that unifies Relativity and Quantum physics will not conceptualize its axioms applying metaphysical notions that are revolutionary different from the strict separability of observer and phenomena of the Newtonian scheme.

Hence, the success of modern physics pose a direct threat to the Newtonian scheme, but, in accounting for modern physics it is the shortcomings of a new conceptual framework, rather than the success of the Newtonian scheme that is the reason the latter is still maintained. The recognition of our failure to comprehend the philosophical implications of modern physics, whether this should be ascribed to our mental conditioning or is simply a matter of impatience, solidifies that a cumulative account is insufficient.

At the very least I think there is no reason to declare the end-of-science.

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[28] "Potentia" or "actus". The abililty to change or to act. Aristotle. (1984).

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